The vertex determination by the sPHENIX INTT in Au+Au collisions

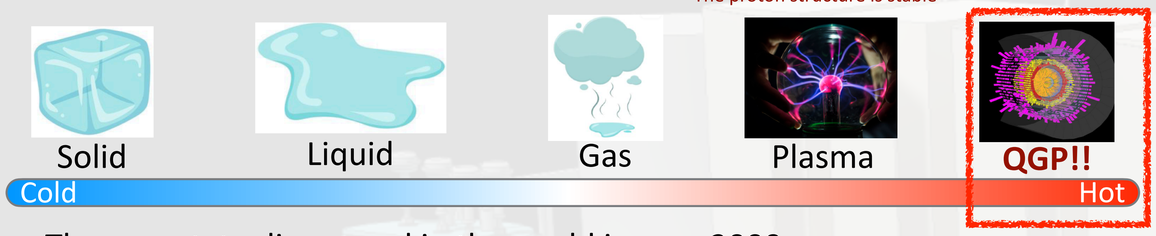
Cheng-Wei Shih *for the sPHENIX Collaboration*

Department of Physics, National Central University, Taoyuan, Taiwan & RIKEN, Wako, Japan

chengwei.shih@RIKEN.jp

Quark-Gluon Plasma (QGP)

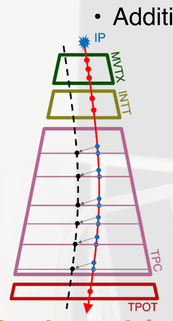
The nuclei cannot hold electron
The proton structure is stable

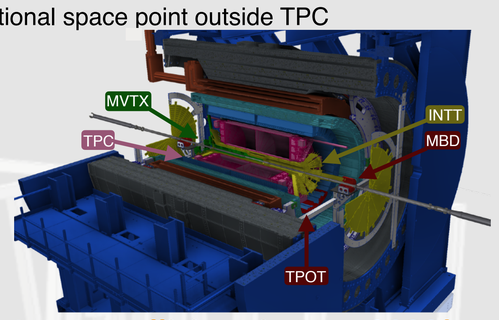


- The new state discovered in the world in year 2000
- A hot and dense state of matter made of quarks and gluons as the strong force cannot hold the quarks
- **The composition of the beginning of universe**
- Can be created artificially by the particle colliders, such as at RHIC

sPHENIX: Full barrel calorimeters, 1.4 T solenoid and excellent tracking system

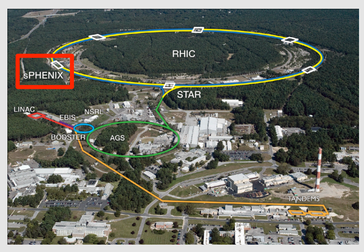
1. MVTX: MAPS-based Vertex Detector
   - Precise collision vertex measurement
2. INTT: Intermediate Silicon Tracker
   - Superb timing resolution
3. TPC: Time Projection Chamber
   - Precise track momentum measurement
4. TPOT: TPC Outer Tracker
   - Additional space point outside TPC

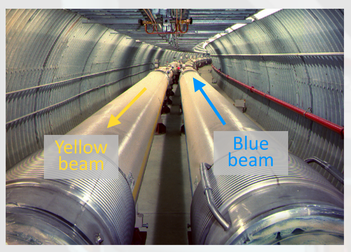


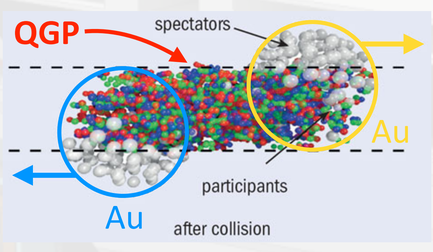


sPHENIX started the commissioning with Au+Au collisions in May 2023!

Relativistic Heavy Ion Collider (RHIC) @ BNL, USA





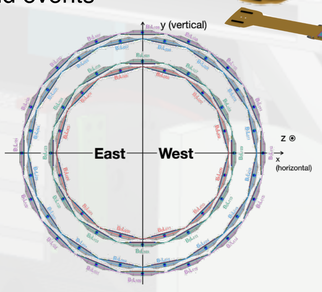


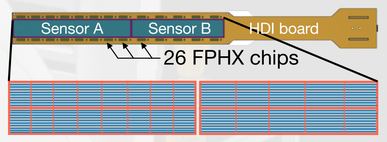
- Two beam pipes with the circumferences of 3.8 km
- Collide two gold ions in near the speed of light to create QGP
- **The environment of ~10^{-6} seconds after the Big Bang can be reproduced**
- Hundreds of particles from the collisions measured the sPHENIX detector

Intermediate Silicon Tracker (INTT)

- Strip width 78 μm → Excellent resolution in ϕ angle
- Between the MVTX and TPC → Bridge the tracks
- Timing resolution 106 ns, best in tracking system
  → Associate individual tracks and events
- Fully funded by RIKEN!!

Element	Value	Unit
Material budget	1.08%	X/X_0
Radius	7.5 or 10	cm
Strip length	16 or 20	mm
Total channels	~ 370k	channel
Readout servers	8	FELIX



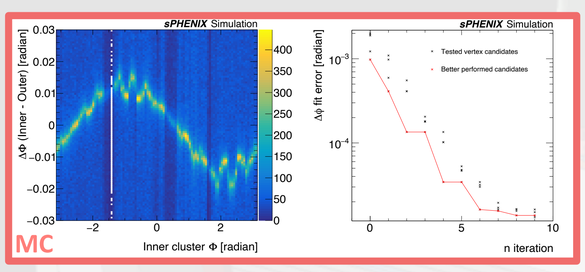


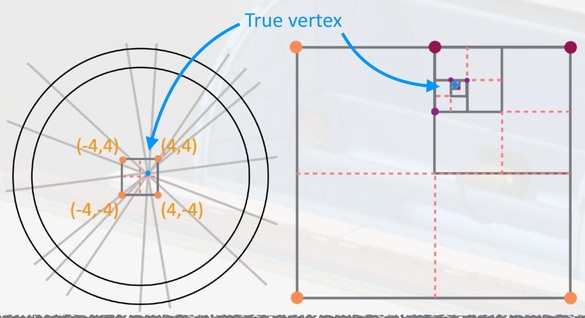
26 sensor cells, 128 channels per cell

Vertex reconstruction by INTT

The first step of measuring the number of charged particles emitted from the collisions as a function of polar angle

Average vertex XY reconstruction





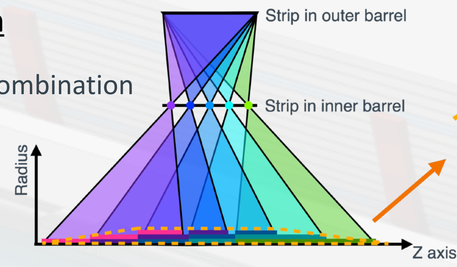
1. Define a large square, and check the performances of corners as vertex candidates
2. Set the new search window to the quadrant with the corner giving better performance
3. Check the performances of the new 4 corners
4. Repeat several times, and confine the true vertex in the ~ 30 μm² square

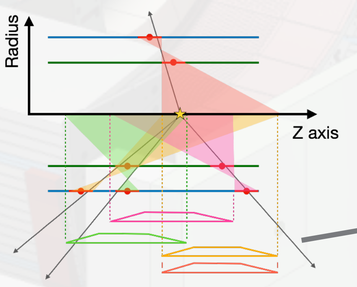
In simulation: (-0.04 cm, 0.24 cm) given, (-0.0403 cm, 0.2397 cm) measured!
In data: (-0.0206 cm, 0.2800 cm) measured!

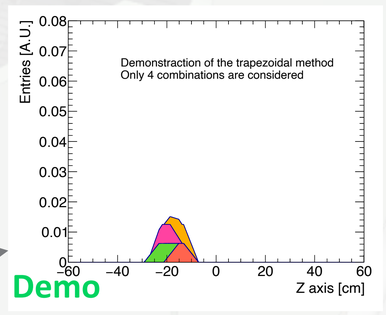
Per-event vertex Z reconstruction

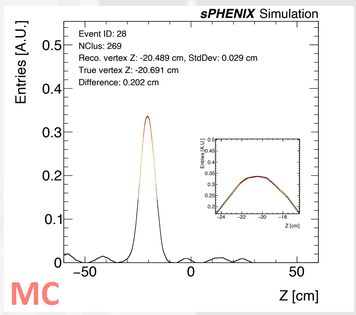
For each combination

The vertex Z probability dist. of one cluster pair is a trapezoidal shape

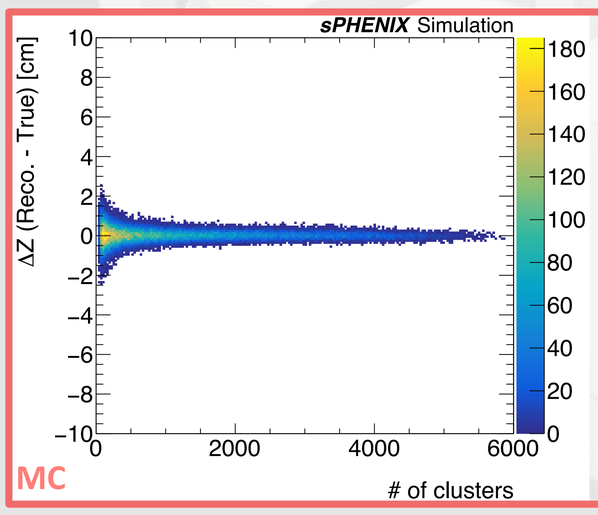


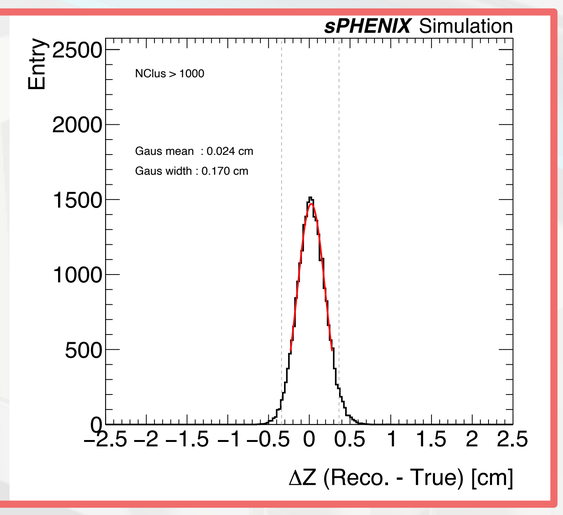


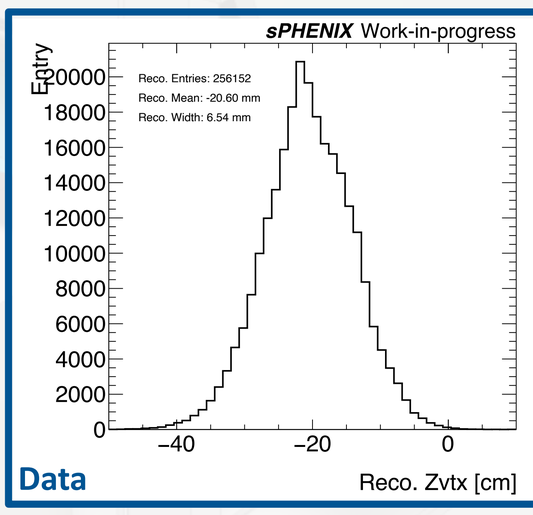


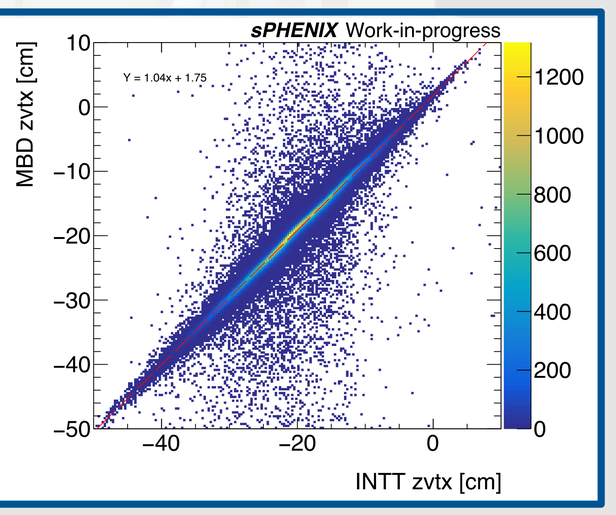


1. Update the cluster ϕ based on the average vertex XY, and find the good cluster pairs
2. Fill the trapezoidal-shaped distributions into the fine-segmented 1D histogram
3. Fit the final distribution with Gaussian functions to determine the final vertex Z









The higher multiplicity the more accurate vertex Z can be determined. 1.7 mm resolution achieved with high multiplicity events
The method has been applied in data, and been validated by comparing with vertex Z reconstructed by Minimum Bias Detector

Conclusion

The study of QGP, the hot and dense material made of quarks and gluons, allows us to have a better understanding of the early university. The particles emitted from the QGP created by RHIC can be measured by the sPHENIX detector. INTT, the barrel strip tracker, has superb timing resolution enabling to associate the tracks to the individual events. INTT was confirmed to be in good shape with the collision data in run 23 commissioning. To measure the number of charged particles, the algorithm of INTT vertex determination is developed. The resolution of vertex Z reconstruction of 1.7 mm is achieved. In addition, the methods have been validated in data.

sPHENIX · RIKEN · 國立中央大學 National Central University · RIKEN's Programs for Junior Scientists · Brookhaven National Laboratory

The vertex determination by the sPHENIX INTT in Au+Au collisions

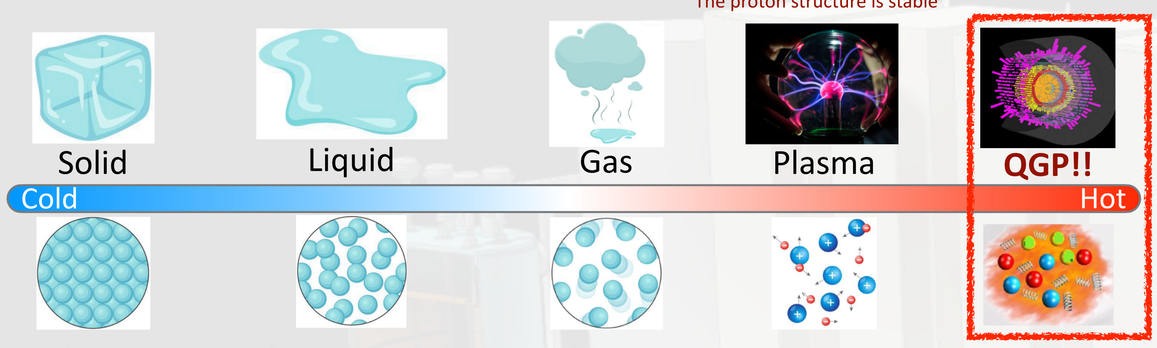
Cheng-Wei Shih *for the sPHENIX Collaboration*

Department of Physics, National Central University, Taoyuan, Taiwan & RIKEN, Wako, Japan

chengwei.shih@RIKEN.jp

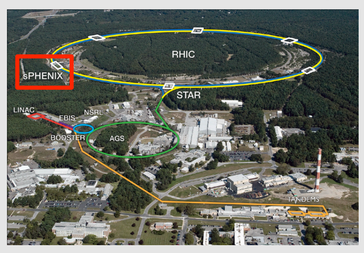
Quark-Gluon Plasma (QGP)

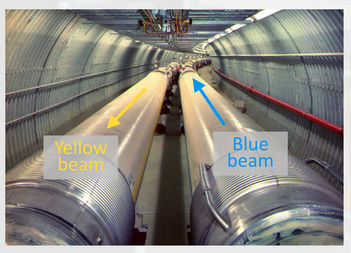
The nuclei cannot hold electron
The proton structure is stable

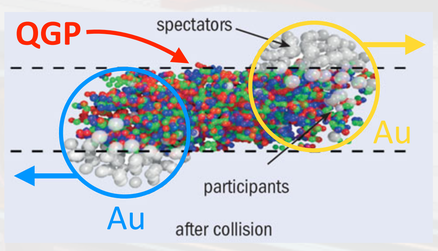


- The new state discovered in the world in year 2000
- A hot and dense state of matter made of quarks and gluons as the strong force cannot hold the quarks
- **The composition of the beginning of universe**
- Can be created artificially by the particle colliders, such as at RHIC

Relativistic Heavy Ion Collider (RHIC) @ BNL, USA



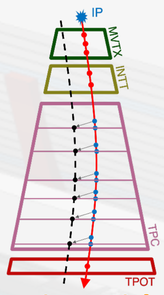


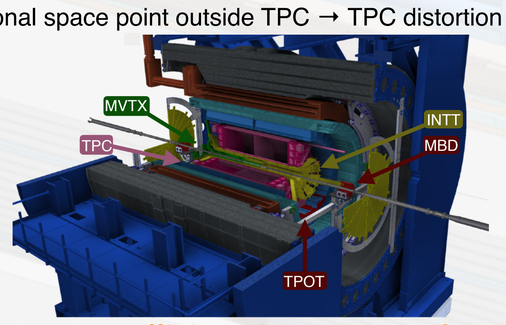


- Two beam pipes with the circumferences of 3.8 km
- Accelerate two gold-ion bunches up to ~99.995% speed of light, and collide each other to create QGP
- **The environment of ~10^{-6} seconds after the Big Bang can be reproduced**
- Hundreds of particles from the collisions measured the sPHENIX detector

sPHENIX: Full barrel calorimeters, 1.4 T solenoid and excellent tracking system

1. MVTX: MAPS-based Vertex Detector
   - Precise vertex measurement → Heavy flavor
2. INTT: Intermediate Silicon Tracker
   - Superb timing resolution → Proton spin
3. TPC: Time Projection Chamber
   - Precise momentum measurement → Upsilon $\Upsilon(3S)$
4. TPOT: TPC Outer Tracker
   - Additional space point outside TPC → TPC distortion

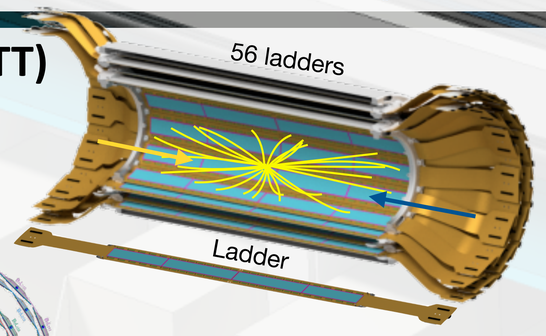




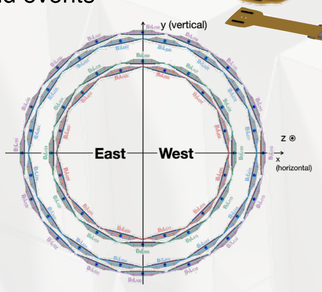
sPHENIX started the commissioning with Au+Au collisions in May 2023!

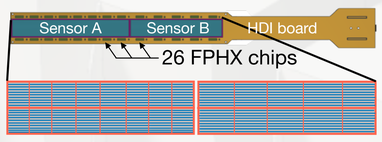
Intermediate Silicon Tracker (INTT)

- Strip width 78 μm → Excellent resolution in ϕ angle
- Between the MVTX and TPC → Bridge the tracks
- Timing resolution 106 ns, best in tracking system
  → Associate individual tracks and events
- Fully funded by RIKEN!!



Element	Value	Unit
Material budget	1.08%	X/X_0
Radius	7.5 or 10	cm
Strip length	16 or 20	mm
Total channels	~ 370k	channel
Readout servers	8	FELIX



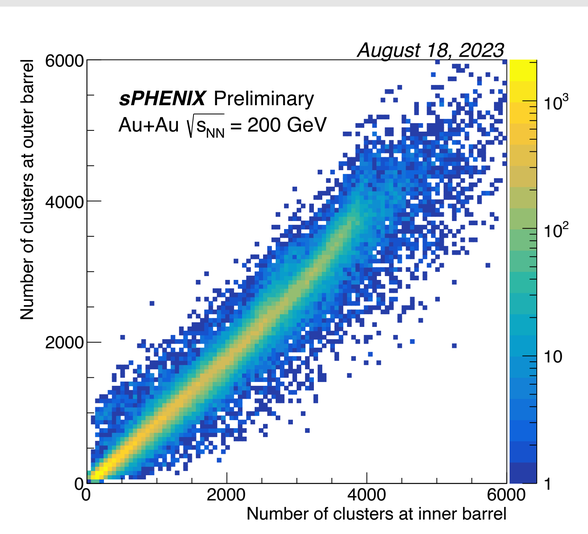


26 sensor cells, 128 channels per cell

Conclusion

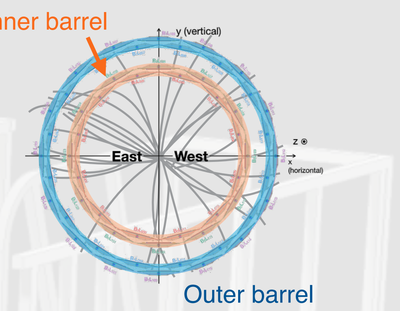
The study of QGP, the hot and dense material made of quarks and gluons, allows us to have a better understanding of the early university. The particles emitted from the QGP created by RHIC can be measured by the sPHENIX detector. INTT, the barrel strip tracker, has superb timing resolution enabling to associate the tracks to the individual events. INTT was confirmed to be in good shape with the collision data in run 23 commissioning. To measure the number of charged particles, the algorithm of INTT vertex determination is developed. The resolution of vertex Z reconstruction of 1.7 mm is achieved. In addition, the methods have been validated in data.

INTT commissioning with Au+Au collisions in 2023



Seen the heavy ion collisions by INTT!

Cluster multiplicity correlation between the inner barrel and outer barrel

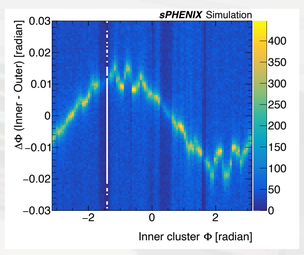


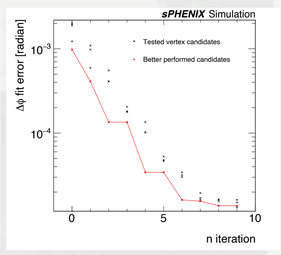
Clear multiplicity correlation observed
→ INTT is in good shape!

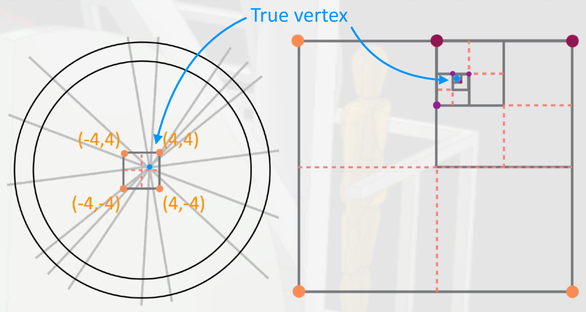
Vertex reconstruction by INTT

The first step of measuring the number of charged particles emitted from the collisions as a function of polar angle

Average vertex XY reconstruction







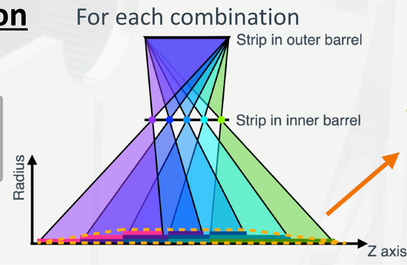
1. Define a large square, and check the performances of corners as vertex candidates
2. Set the new search window to the quadrant with the corner giving better performance
3. Check the performances of the new 4 corners
4. Repeat several times, and confine the true vertex in the ~ 30 μm² square

In simulation: (-0.04 cm, 0.24 cm) set, (-0.0403 cm, 0.2397 cm) measured!
In data: (-0.0206 cm, 0.2800 cm) measured!

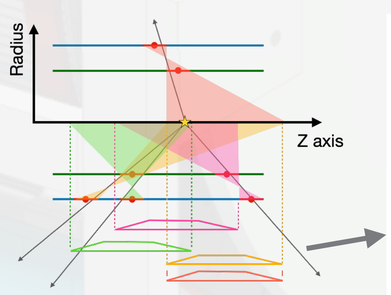
Per-event vertex Z reconstruction

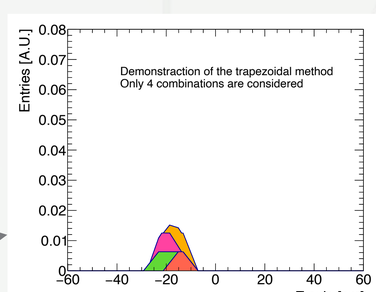
For each combination

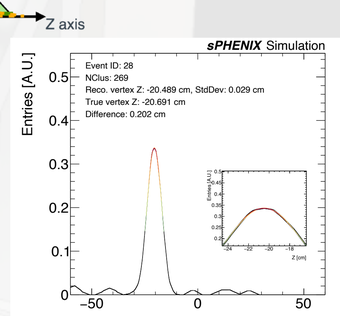
The vertex Z probability dist. of one cluster pair is a trapezoidal shape



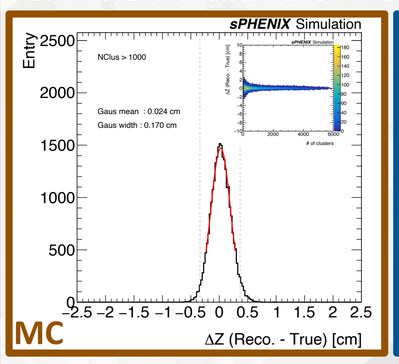
Trapezoidal shape for each combination

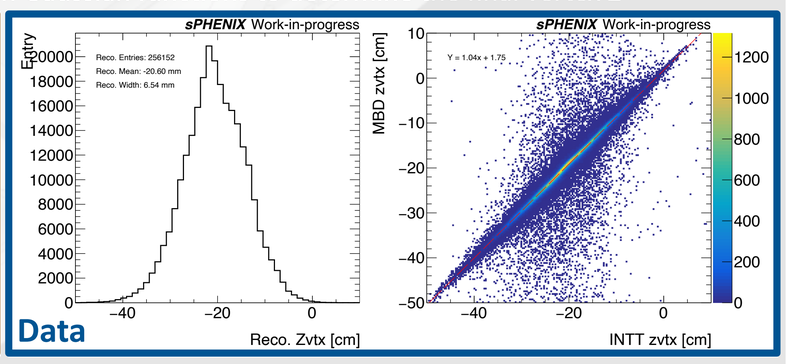






1. Update the cluster ϕ based on the average vertex XY, and find the good cluster pairs
2. Fill the trapezoidal-shaped distributions into the fine-segmented 1D histogram
3. Fit the final distribution with Gaussian functions to determine the final vertex Z





- The higher multiplicity the more accurate vertex Z can be determined
- 1.7 mm resolution in the region of number of clusters > 1000
- The method has been validated in data by comparing with vertex Z reconstructed by MBD

sPHENIX · RIKEN · 國立中央大學 National Central University · RIKEN's Programs for Junior Scientists · Brookhaven National Laboratory